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(54) IMPROVED METHOD AND APPARATUS FOR DISTILLING LIQUIDS

(71) We, THE NASH ENGINEERING COMPANY, a corporation duly organized under the laws of the State of Connecticut, United States of America, of Wilson Avenue, South Norwalk, Connecticut, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method and apparatus for the vapour compression distillation of liquids.

The invention may be used, for example, in the distillation of sea water.

An object of the present invention is to provide a distillation system utilizing a circular lobe liquid ring vapor compressor and providing an extremely efficient flow of liquid and vapor, deriving the maximum possible heat from the system to be applied to the liquid introduced into this system so as to achieve a high efficiency.

In particular, it is an object of an aspect of the invention to provide not only highly efficient heat exchanging relationships between the incoming liquid and the outflowing distillate and liquid-residue, but also to make highly efficient use of overflow liquid for preheating purposes.

According to the present invention there is provided a vapor compression distillation method of distilling a liquid such as sea water, comprising compressing a vapor in a circular lobe liquid ring vapor compressor to a substantially saturated state, said compressor being provided with a rotor, and a frusto-conical inlet and discharge manifold communicating with the rotor of said compressor, directing the compressed substantially saturated vapor through a heat exchanger, passing a liquid feed through the heat exchanger in heat exchanging relationship with the substantially saturated vapor to condense the latter and receive latent heat therefrom, and evaporating the thus heated liquid to form the vapor which is received by said compressor.

The compressor, which is claimed per se in our co-pending Divisional Application No. 8232/69 Serial No. 1211237 is of the circular lobe liquid ring type which has potential advantages over the double lobe type which has been so far thought to have a greater volumetric capacity at a given structure and at a given speed by having the pumping action take place twice in one revolution with the added benefit that the radial pressure against the rotor was balanced because the compression cycles take place simultaneously on opposite sides of the rotor.

Under the conditions that minimum heat transfer should take place between the liquid ring and the vapors being compressed, a double lobe liquid ring compressor would not be able to meet such requirements since in it the liquid ring surfaces are disturbed during transition between the two lobes, whereupon a turbulent interface between the cool ring and the hot vapors is created which circumstance leads to undesired changes in the vapor-pressure characteristics of the vapors being compressed.

In contrast to this, in a circular lobe or single lobe pump, because a single compression cycle takes place only once per revolution, there is more time for the water or other liquid forming the seal to enter and leave the displacement chambers and because the water has a smoother passage around the casing, a smooth liquid-vapor interface is provided with minimum interaction between liquid and vapor along with minimum heat transfer between them with resultant improvement in the net vapor capacity. The vapor compressor may be run at a considerably higher r.p.m. and with considerably greater stroke whereby capacity at least equal to that of a double lobe construction of the same size may be attained in addi-

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tion to the abovementioned advantages of minimum interface between the liquid ring and the vapors.

The vapor capacity per unit of work input in the case of the single lobe compressor is considerably greater than that of the double lobe compressor. Higher speed, work efficiency and the mentioned increase in net vapor capacity is attained because of minimum interaction between the vapor and the smooth liquid ring. The vapor capacity of the single lobe compressor will vary between 106 and 200% of the double lobe compressor with the same basic displacement and power input.

In addition, the efficient vapor compressor employed in this invention includes frustoconical inlet and discharge manifolds which together with the minimum disturbance of the liquid ring make a highly effecient vapor compressor. The frusto-conical inlet and discharge manifold which communicate with the eye of the rotor of the compressor of the invention provide significantly better vapor compression than conventional liquid ring compressor designs, and in addition recirculated relatively cool condensed vapor in the form of a distillate is preferably directed to selected locations within the liquid ring compressor so as to increase the performance and efficiency thereof. The capability of the compressor of the invention to provide a nearly saturated vapor which is discharged from the liquid ring compressor provides a more efficient heat transfer in the condenser tubes of the heat exchanger than, for example, dry superheated vapor discharged by other types of vapor compressors, so that in this way also the performance of the distillation apparatus is improved. It is to be noted that this latter result is achieved without the use of any special accessories since the nearly saturated vapor is derived directly from the compressor itself.

The distillation method and apparatus of the invention include not only a circular lobe liquid ring compressor of the above type, but in addition a main heat exchanger in which preheated feed liquid, such as a sea water feed, is placed in heat exchanging relation with the nearly saturated vapor to condense the latter while receiving latent heat therefrom, after which the preheated feed water is evaporated in a low pressure flash evaporator to provide the vapor which is to be delivered to the compressor. The condensed distillate received from the main heat exchanger is directed through a distillate heat exchanger which additionally preheats the feed water, and part of the distillate is taken from a location downstream of the distillate heat exchanger and is directed to a liquid jacket of a source of power which drives the compressor, so that in this way the cooled distillate receives heat from the source of power. The distillate is then directed from the liquid jacket to the compressor to cool stuffing boxes thereof as well as to receive heat resulting from the friction of the operation of, and the compression produced by the compressor, this latter liquid then being used as makeup liquid for the liquid ring. Part of the liquid from the flash evaporator is directed from an overflow conduit to the liquid which flows to the main heat exchanger so as to mix with the latter, and the remaining part of the overflow liquid passes through an additional heat exchanger for additionally preheating the feed water as it flows from the distillate heat exchanger to the main heat exchanger.

The invention is illustrated by way of example in the accompanying drawings which form part of this application and in which:

Fig. 1 is a schematic illustration of a vapor compression distillation apparatus and method according to the present invention;

Fig. 2 is a sectional elevation of a circular lobe liquid ring compressor of the invention;

Fig. 3 is a sectional elevation perpendicular to Fig. 2 showing further features of the compressor illustrated therein; and

Fig. 4 shows a variation of Fig. 1.

Referring to Fig. 1, a sea water feed conduit 10 feeds liquid, such as sea water, through a distillate heat exchanger 12 in which the feed water is preheated as it recovers waste heat while flowing through the distillate heat exchanger 12. A conduit means 14 directs the feed water from the distillate heat exchanger 12 through a blow down heat exchanger 16 from where the preheated feed water is received by an additional conduit 18 which directs the liquid to a main heat exchanger 20.

A circular lobe liquid ring compressor 22, the details of which are described below in connection with Figs. 2 and 3, has an inlet communicating with an inlet conduit 24 for receiving from flash evaporator 36 a vapor which is compressed to a nearly saturated state in the compressor 22. A discharge conduit 26 receives the nearly saturated vapor and directs it through the main heat exchanger 20 so as to preheat the feed water delivered to the main heat exchanger 20, after passing through the preheater heat exchanging 2 and 16.

In this way the vapor flowing through the discharge conduit 26 is condensed in the main heat exchanger 20, to form a distillate flowing along the discharge conduit 26 through the distillate heat exchanger 12, and thus sensible heat is given up to the liquid in the main heat exchanger 20. A heating unit 28 may be provided for producing a minimum amount of heat to be added to the liquid in the main heat exchanger 20 so as to make up for heat losses, although usually the heat derived from a source of power 30 for the compressor 22 and from the compressor 22 itself will suffice.

The preheated liquid mixture in the main heat exchanger 20 is delivered through a conduit 32, which may optionally be provided with a pressure differential valve 34, to a low

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pressure flash evaporator 36. The vapor which results from the evaporation in the evaporator 36 flows through the inlet conduit 24 to the inlet of the compressor 22.

An overflow conduit 38 receives overflow brine from the evaporator 36 and part of this overflow liquid is directed through a conduit 40 to the conduit 18 to mix with the liquid therein before the latter liquid reaches the main heat exchanger 20. A recirculating brine pump 42 is carried by the conduit 40 for directing part of the overflow liquid into the conduit 18 so as to mix therein with the preheated liquid derived from the blow down heat exchanger 16.

The remaining overflow continues to flow through the conduit 38 which passes through the blow down heat exchanger 16 so as to reject its sensible heat to the sea water feed which flows through the heat exchanger 16 from the portion 14 and to the portion 18 of the conduit which directs preheated liquid from the distillate heat exchanger 12 to the main preheater 20. The flashed vapor which flows through the conduit 24 to the compressor 22 is raised to a higher pressure and temperature by the circular lobe liquid ring compressor 22 of the invention. The hotter, nearly saturated vapor is then discharged through the discharge conduit 26 into the main vapor heat exchanger 20 as the latent heat of condensation of the vapor is transferred to the brine mixture flowing through the main heat exchanger 20.

The distillate flowing through the discharge conduit 26 downstream of the main heat exchanger 20 rejects its sensible heat to the sea water feed in the distillate heat exchanger 12, and the cooled distillate continues to flow from the distillate heat exchanger 12 through an optional pressure reducing valve 44 to the distillate receiver 46.

A coolant conduit 48 communicates with the discharge conduit 26 downstream of the distillate heat exchanger 12 to receive a part of the cooled distillate therefrom, and this coolant conduit 48 directs this part of the distillate to a water jacket 50 of the power source 30 which may be in the form of a water-jacketed motor. From the water jacket 50 a conduit 52 directs the heated distillate to the compressor 22, so that in this way heat losses are recovered from the power source 30 and in addition the liquid from the conduit 52 is used to lubricate and cool the compressor stuffing boxes, to provide makeup for the compressor liquid ring and to absorb most of the heat of compression and friction of the compressor.

If desired, the sea water feed may be circulated in place of the cooled distillate through the water jacket of the compressor power source 30.

Referring to Figs. 2 and 3, the circular lobe liquid ring compressor 22 illustrated therein includesa cylindrical or other shaped single lobed casing member 60 which at its ends is closed by enclosing heads 61. A main drive shaft 62 rotationally mounted in a pair of bearings 63 of which only one is shown, since Fig. 3 is showing only half of the compressor the other half being broken away. The shaft 62 supports a rotor 64 which is suitably secured, such as by keyins, thereto. Shaft 62 is situated at an elevation lower than and to one side of the axis of the casing 60 while being parallel to the latter axis, so that the shaft 62 is eccentrically situated with respect to the casing 60.

In order to prevent liquid seepage about the rotating shaft, liquid sealing packing and gland assemblies 96 are fitted into the heads 61 at both ends of the compressor.

The rotor 64 is of the duplex variety containing a plurality of radially extending pumping chambers 65 defined therein by blades 66, side shrouds 67 and a central partition wall 68, which is in line with a corresponding partition wall 69, in the casing 60 to form adjacent crescent shaped lobed pumping chambers 68′. Disposed at each end of the pump are a pair of frustoconical inlet passages 74 (of which only one is shown) formed in the heads 61 and which direct inlet vapor to right and left hand port members 76. Inlet passages 74 communicate with conduit 24. The port members include inlet passages 78 in communication with the pumping chambers 65 within the rotor and discharge ports 80 also in communication therewith. The discharge ports 80 through a frusto-conical discharge passage 90 communicate with a header chamber 81 formed in each head 61 to provide access to several alternate discharge port flanges 82 located on the lower sides and bottom of the head.

The compressor is mounted such that its inlet chamber 84 and its outlet chamber 86 are separated by a partition 96 situated in a plane located between a horizontal plane including the shaft axis and between a vertical plane which includes the axis of shaft 62, as seen in Fig. 2, with the compressor band being situated in the plane of the partition 96. An illustrative location of the partition 96 is shown as being about 45° from the horizontal plane.

In operation, the receding of liquid within chambers 65 in the area of the intake port 78 creates a void thereby a suction in passage 74, and when forced back toward the center of the rotor, produces compression through port 80.

The cooled recirculated distillate delivered by the conduit 52 to the compressor 22 is delivered to the location 94 (Fig. 3) where it will cool and lubricate the gland assemblies 96′ and provide makeup for the liquid ring 98 as well as absorb part of the heat input due to the work of compression and friction.

It will be noted that with this construction the liquid ring 98 rotates in a very smooth manner so that there will be a minimum of heat transfer between the relatively hot com-

pressed vapor and the liquid ring, and minimum vapor capacity loss due to vapor flashing as the liquid ring passes through the low pressure inlet portion of the cycle.

The above-described compressor configuration, with the described features such as the attitude of the inlet and outlet ports and the frustoconical manifold portions effect an efficient movement of vapor through the compressor with minimum contact between the hot discharge vapor and the relatively cool liquid ring 98. The large vapor capacity and higher temperature compression differentials are achieved with relatively less power than can be achieved with other compressors, and a significant improvement in performance of the vapor compression distillation is achieved from the compressor 22.

In particular, the nearly saturated vapor which can be discharged directly from the compressor 22 makes for a more efficient heat transfer in the condenser tubes of the distillation system used in accordance with the method of the invention.

In the variation shown in Fig. 4, additional heat exchanging can be provided so as to achieve additional preheating of the feed water. For this purpose, the feed water is introduced through a conduit 100 which has a pair of branches 102 and 104 respectively leading to the further heat exchangers 106 and 110. The heat exchanger 106 receives the conduit 38 which passes through the heat exchanger 106 so as to give up heat to the feed water introduced through the branch 102, and this latter feed water then issues from the heat exchanger 106 through the conduit 108 so as to flow into the supply conduit 10 referred to above.

The distillate which flows through the conduit 26 passes through the other heat exchanger 110 so as to give up additional heat to the feed water flowing into the heat exchanger 110 through the conduit 104, and this latter feed water then flows out of the heat exchanger 110 through the conduit 112 to also be received by the conduit 10 referred to above and shown in Fig. 1. From the conduit 10 the feed water, which now has been additionally preheated, flows in the manner described above in connection with Fig. 1. Except for these differences the embodiment of Fig. 4 is precisely the same as that of Fig. 1.

WHAT WE CLAIM IS: :—

1. A vapor compression distillation method of distilling a liquid such as sea water, comprising compressing a vapor in a circular lobe liquid ring vapor compressor to a substantially saturated state, said compressor being provided with a rotor, and a frusto-conical inlet and discharge manifold communicating with the rotor of said compressor, directing the compressed substantially saturated vapor through a heat exchanger, passing a liquid feed through the heat exchanger in heat exchanging relationship with the substantially saturated vapor to condense the latter and receive latent heat therefrom, and evaporating the thus heated liquid to form the vapor which is received by said compressor.

2. The method according to claim 1, in which the distillate is directed through an additional heat exchanger before being collected in a receiver, said liquid feed being fed through the additional heat exchanger before it reaches said first-mentioned heat exchanger so that the liquid feed reaches the latter in a preheated condition.

3. The method according to claim 1 or 2, comprising directing part of the distillate which has been additionally cooled in said additional heat exchanger to a liquid jacket to receive heat from a power source for the compressor, and directing the heated liquid from the power source to the compressor to cool the stuffing boxes thereof, to receive heat therefrom and to form makeup liquid for a liquid ring of the compressor.

4. The method according to claim 2 or 3, in which said evaporation is effected in a low pressure flash evaporator, overflow liquid being directed away from said evaporator with part of the overflow liquid recirculated with liquid flowing from said additional heat exchanger to said first-mentioned heat exchanger.

5. The method according to claim 4, comprising providing a third heat exchanging transfer between the overflow liquid and the liquid flowing from the additional heat exchanger to the first-mentioned heat exchanger.

6. The method according to claim 5, in which the third heat exchanging transfer is provided in the liquid flowing to the first-mentioned heat exchanger before the latter liquid mixes with recirculated overflow liquid.

7. Vapor compression distillation apparatus comprising a circubular lobe liquid ring vapor compressor having an inlet and an outlet, an inlet conduit communicating with said inlet for supplying to said compressor vapor to be compressed therein, said compressor discharging the vapor at said outlet thereof in an almost saturated state, a discharge conduit communicating with said outlet of said compressor for receiving the compressed vapor therefrom, a main heat exchanger through which said discharge conduit passes, a distillate heat exchanger through which said discharge conduit also passes, a supply conduit communicating with said distillate heat exchanger for supplying liquid to be placed in heat exchanging relationship with said discharge conduit in said distillate heat exchanger for preheating said liquid, and an additional conduit communicating with said distillate heat exchanger and said main heat exchanger for directing said preheated liquid from said distillate heat exchanger to said main heat exchanger to be placed in the latter in heat exchanging relationship with said discharge conduit in said main heat exchanger

before said liquid is received by a low pressure flash evaporator, said liquid in said main heat exchanger being heated by the heat liberated by the condensation of the compressed vapor in said discharge conduit, and said flash evaporator communicating with said main heat exchanger to receive the heated liquid therefrom and to flash the liquid into a vapor, and said inlet conduit communicating with said evaporator for receiving the vapor therefrom and directing it to said inlet of said compressor.

8. Apparatus according to claim 7, comprising drive means operatively connected with said compressor for driving the latter, said drive having a water jacket, coolant conduit communicating with said discharge conduit at a part thereof situated downstream of said distillate heat exchanger and directing part of the distillate from said discharge conduit to water jacket to receive heat from said drive, said coolant conduit having a portion extending from said water jacket to said compressor for cooling stuffing boxes thereof, for receiving heat therefrom, and for providing makeup liquid for a liquid ring in said compressor.

9. Apparatus according to claim 8, comprising an overflow conduit communicating with said evaporator for directing overflow liquid away from the latter, and a recirculating conduit communicating with said overflow conduit and with said additional conduit for recirculating part of the overflow liquid to the liquid which flows through said additional conduit from said distillate heat exchanger to said main heat exchanger.

10. Apparatus according to claim 9, in which a blow down heat exchanger is interposed in said additional conduit so that the liquid flows through said blow down heat exchanger after leaving said distillate heat exchanger and before reaching said main heat exchanger, as well as before mixing with overflow from said evaporator means, said overflow conduit passing through said blow down heat exchanger whereby the liquid supplied to said flash evaporator is first preheated in said distillate heat exchanger and then in said blow down heat exchanger before reaching said main heat exchanger in a condition mixed with recirculated liquid from said evaporator.

11. Apparatus according to any one of claims 7 to 10, in which a further heat exchanger is situated upstream of said distillate heat exchanger for receiving said discharge conduit after the latter passes through said distillate heat exchanger and a further conduit communicating with and situated upstream of said supply conduit and directing liquid in heat exchanging relationship with said discharge conduit through said further heat exchanger before the liquid reaches said supply conduit, so that the liquid is in a preheated condition before arriving at said supply conduit.

12. Apparatus according to claim 11, in which a still further heat exchanger is situated upstream of said blow down heat exchanger and receiving said overflow conduit, and additional conduit directing liquid in heat exchanging relation with that part of said overflow condit which passes through said still further heat exchanger means, said further conduit directing the liquid after passing through said further heat exchanger to said supply conduit, so that the liquid is preheated before reaching said supply conduit.

13. A method of distilling a liquid, substantially as hereinbefore described with reference to Figures 1 to 3, or Figures 1 to 3 modified as shown in Figure 4, of the accompanying drawings.

14. Apparatus for distilling a liquid, substantially as hereinbefore described with reference to Figures 1 to 3, or Figures 1 to 3 modified as shown in Figure 4, of the accompanying drawings.

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig.1.

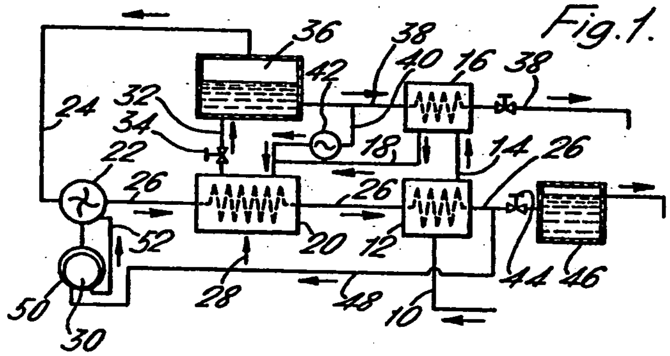
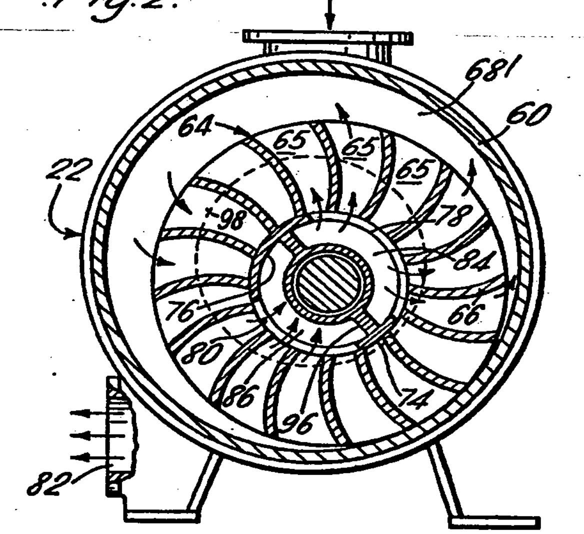


Fig.2.



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Sheet 2

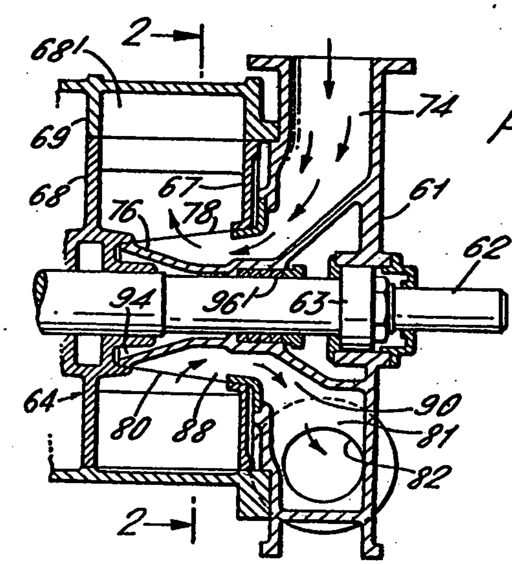
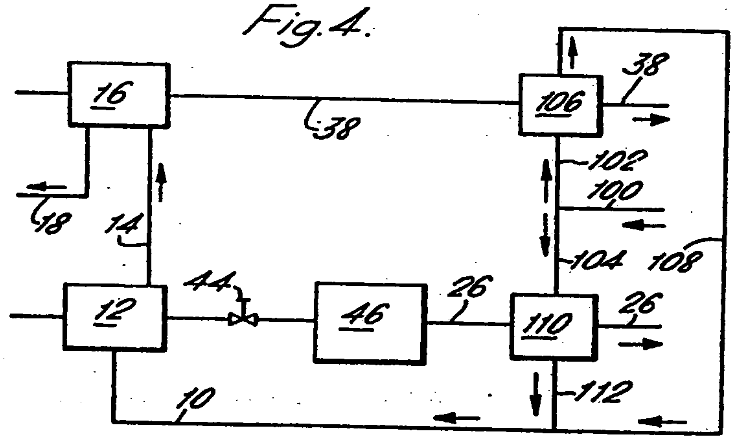


Fig.3.

Fig.4.



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